HYDRODYNAMICS AND WATER QUALITY NUMERICAL MODEL:
MASS1 - Modular Aquatic Simulation System Model 1D

SUMMARY:

MASS 1 is a one dimensional, unsteady hydrodynamic and water quality model for river systems. It was developed to be used on branched (tree-like) channel systems and has been extensively applied by Battelle Pacific Northwest Division to the Columbia and Snake rivers. The model simulates cross-sectional average values; only single values of water surface elevation, discharge, velocity, concentration, and temperature are computed at each point in the model, at each time interval.

HYDRODYNAMICS:

Unsteady flows in rivers or canals are simulated by solving the one-dimensional equations of mass and momentum conservation called St. Venant equations. The friction slope term can be computed using either the Manning or Chezy equations. The friction slope is expressed in terms of discharge and channel conveyance, and the conveyance is computed using the Manning equation. Lateral inflows and outflows can also be included.

WATER QUALITY CONSTITUENTS:

General Capabilities - Water quality constituents are modeled through the solution of a general transport equation (including source/sink terms) that is derived from application of the conservation of mass principle to channel reaches of the river system. Any number of constituents can be simulated (subject to computer memory limitations). Lateral inflow and outflow of constituents can be simulated.

Total Dissolved Gas - Calculation of TDG pressures and saturations from concentrations is accomplished using relationships presented in the Colt (1984) American Fisheries Society Report. Air is assumed to be composed of a limited number of individual gases and the Bunsen coefficient is computed as an aggregate of the coefficients for individual gas fractions. Individual gas fraction coefficients are computed as functions of temperature and salinity, as is vapor pressure. A general cubic polynomial equation was developed to fit empirical surface gas exchange data (O'Conner, 1982, J. Environmental Engineering).

Water temperature - The principle of conservation of energy to a channel reach is applied, relating to the internal energy to temperature, and averaged over a cross-section. Heat exchange at the water surface is computed as the heat flux. When measured radiation is available, the net solar short radiation is computed. When not available, net incoming short-wave radiation is computed using Brown and Barnwell (1987, EPA, Environmental Research Laboratory). The albedo is computed according to Brown and Barnwell.. The net atmospheric long wave radiation, long back wave radiation, evaporation heat flux, and conduction heat flux are computed using Edinger (1974, Electric Power Research Institute

Report). Meteorological conditions can be assigned on a zonal basis using multiple weather stations.

MODEL TOPOLOGY:

The model is general purpose and can be applied to any river system that can be represented as a branched network. The river system is divided into a series of links that are further divided into a series of computational points along that link. Nodes occur at upstream or downstream boundary points and at the junction of two or more links. The model requires bathymetry as a series of cross-sections.

In the Columbia River Basin, the upper boundaries of the modeled region are the US/Canadian border on the Columbia, Dworshak Dam on the North Fork of the Clearwater River, and Hells Canyon Dam on the Snake River. The downstream boundary is near Astoria, Oregon. Model boundary conditions such as inflows, project operations, and meteorology can be specified on any time interval. Typically project operations are specified on a hourly basis and tributary flows are assigned daily flows or assumed constant. They were spaced approximately 1/4 mile in the first few miles below the dams, and in the Hanford reach, and 1/2 mile interval elsewhere. The sources of meteorological data were Lewiston, Pasco, The Dalles, and Portland.

SOLUTION METHODS:

The equations are individual and coupled systems of linear and nonlinear partial differential equations. Finite-difference methods are used to solve the equations. The hydrodynamic equations are discretized using Preissmann four-point implicit finite-difference scheme and the resulting system of nonlinear algebraic equations are solved using the Cunge (1980) double sweep method. The various transport equations are solved using the split-operator method. The advective part is solved using an explicit TVD scheme to minimize numerical dispersion. A time sub-cycling scheme is used to allow the hydrodynamics calculations to use the higher time step allowed by the implicit method.

STATUS: The model is actively maintained, supported, and enhanced.

SYSTEM: Windows and Unix/Linux systems. Code is written in FORTRAN90.

GRAPHICAL USER INTERFACE: Not currently available.

PRE-PROCESSORS: None required, but GIS and database utilities have been developed to create cross-section and boundary condition data.

POST-PROCESSORS: Model output is in form of text files for user specified time series locations or for profiles along the channel system. Results can be plotted using standard spreadsheet software or other plotting programs.

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USER MANUAL: Notes, slides, and examples are available from training workshops. A user manual is in progress.

PROJECT ABSTRACTS:

Dissolved Gas Abatement Study: MASS1 was configured to simulate approximately 800 miles of the lower Columbia and Snake Rivers, including 15 hydroelectric projects. The model was calibrated for temperature and total dissolved gas transport using in-stream monitoring data from 1996 and 1997. Several dissolved gas abatement scenarios, involving changes to the dam operation and spillway gas production, were simulated to compare the system-wide impact of the scenarios on dissolved gas levels.

Lower Snake River Feasibility Study: MASS1 was configured to simulate approximately 170 miles of the lower Snake River including 4 hydroelectric projects. The model was calibrated for temperature using in-stream monitoring data from 1996 and 1997. Using inflow conditions for a 35-year period, MASS1 was used to simulate the water temperature with the dams in place (current conditions) and supposing the dams were removed (unimpounded conditions). The results compared to determine the effect, on temperature, of breaching the dams.

Hanford Reach Juvenile Salmon Stranding: MASS1 was configured to simulate the hydrodynamics of the Hanford Reach, the remaining unimpounded section of the Lower Columbia River, which included approximately 100 river miles. The hydrodynamics model was calibrated using several in-stream stage monitors located along the Reach. Simulation results were used to identify areas where the widely fluctuating river stage (caused by upstream hydroelectric project operation) might cause salmon smolt to become stranded above the waterline along the shore. MASS1 was also used to forecast river stages at locations of interest to field crews.